BIMing the Architectural Curricula – Integrating Building Information Modelling (BIM) in Architectural Education

Abstract –

Building Information Modelling (BIM) reflects the current heightened transformation within the Architectural, Engineering and Construction (AEC) Industry and the Facilities and Management (FM) sector, offering a host of benefits from increased efficiency, accuracy, speed, co-ordination, consistency, energy analysis, project cost reduction etc to various stake holders from owners to architects, engineers, contractors and other built environment professionals. Many countries around the world are responding to this paradigm shift including the United Kingdom (UK). The Cabinet office took the decision in 2011 to make the use of collaborative 3D BIM technology mandatory for all public sector construction contracts by 2016 (Cabinet Office, 2011). According to Smith and Tardif, despite certain myths and misconceptions surrounding BIM, its rate of implementation has been much faster in comparison to the availability of professionals skilled in use of BIM, thus creating a skill gap in the design and construction industry (Smith and Tardif, cited in Barison and Santos, 2010a).

This article aims at bridging the gap between the graduate skill sets and the changing needs of the profession. The research methodology adopted consists of thoroughly reviewing the existing literature in this subject area coupled with carrying out a survey of accredited Schools of Architecture in the UK. The analysis of the survey questionnaire results shows the extent to which BIM is currently being taught and identifies the barriers where its implementation has either been slow or not yet started. The paper highlights the fact that there has been considerable delay in the successful integration of BIM in the Schools of Architecture in the UK, thus emphasising the need for expeditiously training and preparing students in the use of BIM making them ready to effectively perform in a BIM enabled work arena.

Keywords: Building Information Modelling (BIM), Architectural Engineering and Construction (AEC) Industry, graduate skill set, Architectural curricula.

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Introduction –

Building Information Modelling or BIM is transforming the way architects, engineers, contractors, and other building professionals work in the industry today. Eastman in the BIM Handbook, describes Building Information Modelling as an innovative way to design, fabrication, pre and post construction and operations and management in comparison to the traditional way of drawing and views it as more of a human activity i.e. modelling, instead of seeing it as an object oriented approach or being a particular software (Eastman, C., et al., 2008). BIM can be said to have evolved out of CAD, which itself has come a long way since its development from its predecessor PRONTO in 1957, the first numerical control programming tool. It then led to the development of Sketchpad in 1963 where for the for the first time the user was able to interact with the software as can be seen in Figure 1 below (Tornincasa, S. and Monaco, F.Di., 2010).

Figure 1: Ivan Sutherland working with Sketchpad using a light pen on a CRT monitor screen
[Source: Tornincasa, S. and Monaco, F.Di, (2010)]

The concept, approach and methodologies of BIM can be traced back to at least 35 years as is evident from Chuck Eastman's prototype definition proposed in 1975:

> [designing by]"…interactively defining elements…derive[ing] sections, plans, isometrics or perspectives from the same description of elements...Any change of arrangement would have to be made only once for all future drawings to be updated. All drawings derived from the same arrangement of elements would automatically be consistent…any type of quantitative analysis could be coupled directly to the description...cost estimating or material quantities could be easily generated … providing a single integrated database for visual and quantitative analysis…automated building code checking in city hall or the architect's office. Contractors of large projects may find this representation advantageous for scheduling and materials ordering" (Eastman, C.,1975 cited in Eastman, C., et al.,2008).

Building designs have been for decades communicated through documents that have been inconsistent with each other (Eastman, C., et al., 2008). CAD generated documents have often omitted vital information that is needed for efficient design assessment. According to Watson, one of the central reasons that led to the development of BIM was aimed at resolving this particular flaw of inconsistencies creeping in 2D CAD. Although BIM builds its base on the success of traditional CAD applications, the rational behind BIM is the object-oriented paradigm for design (Watson, 2010).

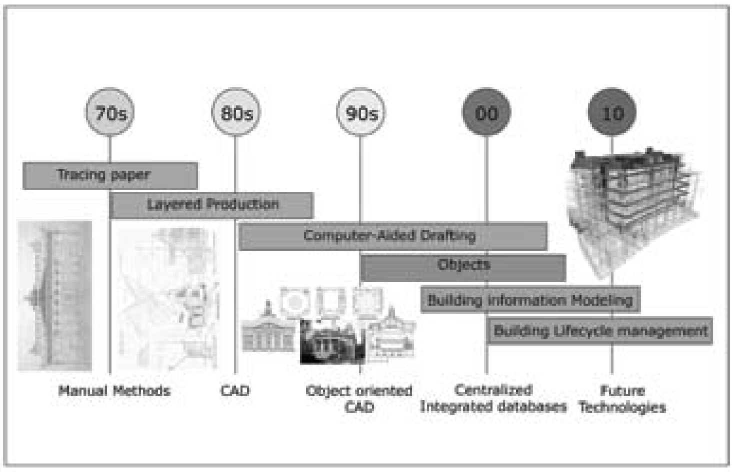


Figure 2: Schematic diagram representing the evolution of Architectural documentation
[Source: Kumar, J.V. and Mukherjee, M.(2009)]

For the AEC industry, BIM has been one of the most promising developments of our times as it allows creating an accurate virtual model containing precise geometry and other relevant information aiding in modelling the entire lifecycle of a building (Eastman, C., et al., 2008). There are however many myths and misconceptions that exist around BIM causing huge concerns in the UK construction industry, since the government has made the use of 3D collaborative BIM mandatory for all public sector construction contracts by 2016. The structure of this paper begins by looking at the wide variety of definitions proposed by various authors, researchers, scholars etc from this field to have a thorough understanding of the key perspectives before we arrive at an agreeable working definition for this paper. It then analyses the numerous benefits it brings to the various stake holders from owner to built environment professionals in comparison to previously working with traditional 2D CAD. The paper further identifies the key issues and barriers in the way of implementing BIM in practices and schools of architecture. It then studies real life projects across the globe where the use of BIM has brought about massive savings in time, cost etc. amongst other benefits. The paper reviews the various initiatives taken by Universities which have attempted to teach BIM within the built environment related courses. It finally evaluates findings from a survey questionnaire completed by Schools of Architecture in the UK, providing evidence that very little has been done till now in teaching BIM, thus highlighting the urgent need for expeditiously training and preparing students with appropriate skills to be able to effectively work in a BIM enabled environment. The paper concludes by proposing the best practice model for teaching and integrating BIM into the architecture curricula in order to meet the needs of this growing demand.

What is BIM? – Definitions of BIM

The Royal Institute of British Architects (RIBA), Construction Project Information Committee (CPIC) and Building Smart have jointly defined BIM as "digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition"(CPIC, 2011).

Building Smart, a non profit organisation that supports open BIM, defines it as a digital model of a building with information structured and shared in a 3D / 4D or even 5 dimensions integrating components of time and cost (Building Smart, 2010:2). According to Ashcroft, et al in BIM - A Framework for Collaboration:

> "A building Information Model, or BIM, utilizes cutting edge digital technology to establish a computable representation of all the physical and functional characteristics of a facility and its related project/life-cycle information, and is intended to be a repository of information for the facility owner/operator to use and maintain throughout the life-cycle of a facility" (National Institute of Building Sciences (NIBS) quoted in Ashcroft, H.W., 2007:2).

Joseph, attempts to break down BIM into B standing for shapes / functionality / spaces / construction, I for information / set of data / input / materials / studies and M for representation / modelling / virtualizing / pre-constructing (Joseph, J., 2009). Kymmell, breaks it further and makes the point that BIM has surpassed virtual models and represents intelligence, because of possessing real life physical information within the model (Kymmell, 2007:31). M. A. Morteson company share a similar view to Kymmell and consider BIM as "intelligent simulation of architecture" exhibiting digital, spatial (3D), measurable, comprehensive, accessible and durability as BIM's six key characteristics. National Institute of Building Science (NIBS), also focuses on the 'The process view' with one of the three categories of the process identified as: Intelligent representation of data – authoring tools, Collaboration process and a facility lifecycle management (National Institute of Building Science (NIBS), 2007). Eastman holds a more balanced and comprehensive view of BIM and sees it more as a collection of tools and processes to produce and analyze models of building instead of simply focussing on technology or a product as is the case with some others (Eastman, C., et al., 2008:13).

We agree with Eastman's view of BIM that there are two clear aspects, the process that goes into producing the final product involving data input, coordination, collaboration, skills etc and the product or the model produced which is used for construction, analyzing environmental impact, life cycle maintenance etc. We however firmly believe that 'intelligence' which contains the real time physical information within the digital model should be seen as the third and most significant element characterizing BIM.

Table 1: Definitions of BIM – The three categories of BIM i.e A) Process, B) Product and C) Intelligence

Definition of BIM	**Authors/Scholars/Researchers/ Organisations**
Category A) Process /Technology/New way of working	(Building Smart, 2010:1)
"Process of generating and managing data about the building, throughout its entire life cycle"	(Smith,M.,2011)
"A collaborative process of design, procurement and building operations''	(NBS, National BIM report, 2012)
'The process view' with three categories as Intelligent representation of data – authoring tools, Collaboration process and a facility lifecycle management.	(National Institute of Building Science, NIBS 2007)
"A disruptive technology" as it will transform many aspects of the AEC industry.	(Eastman et al, cited in Sabongi, J.F) (Davidson, A.R.,2009)
Category B) Product/Digital model with information structured and shared in a 3D / 4D / 5D right to 'nD'	(Building Smart, 2010:2)
"Digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition"	Joint definition by (RIBA, CPIC & Building Smart for the UK Construction Industry)
Category C) Intelligence Migration from 2D to 3D and creating intelligent and multi-dimensional building models.	(Ready, 2007 cited in Sabongi, J.F Kymmell, 2007:31)
" Intelligent simulation of Architecture" exhibiting the following six key characteristics : digital, spatial (3D), measurable, comprehensive, accessible and durable.	(M.A.Mortenson Company); (Eastman :2008 :13)

[Source : Building Smart; (2010), Smith, M., (2011), NBS, National BIM report (2012), NIBS (2007) and others]

Although the capabilities, potentials and benefits of BIM are immense, but it is important that each stake holder in the process customizes its use to suit their own requirements. Some stakeholders will capitalize more from employing it as a technology or a process emphasizing on sharing information within the team and others simply by viewing it as a product or a virtual model. The next section of the paper looks at the various benefits of using BIM and shows how much the stakeholders can gain from going beyond the traditional 2D CAD approach.

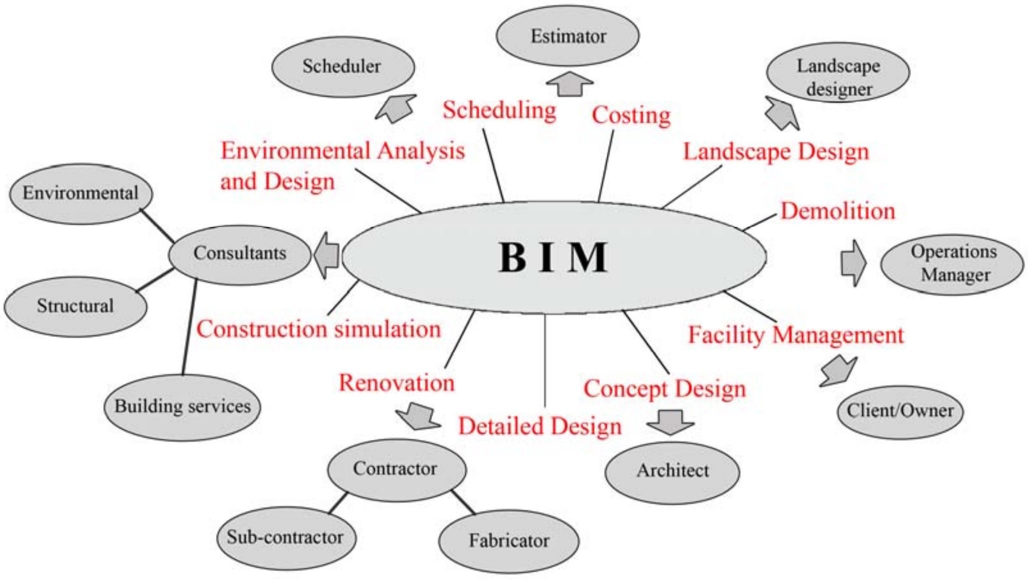


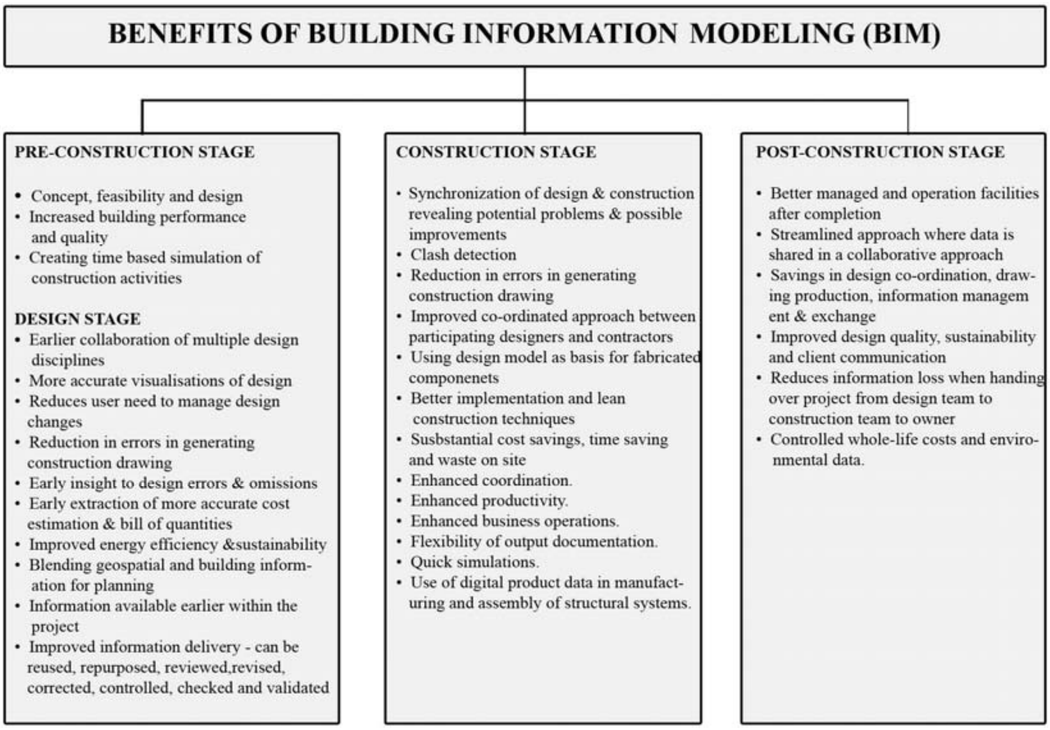
Figure3 : BIM – Various stakeholders and provision of services in the AEC industry
[Source : Author's own]

Benefits of BIM to various stake holders during the design, construction, facilities and operations stage

BIM has far reaching benefits in the AEC/FM industry in supporting and improving business practices compared to traditional practices that are paper-based or 2D CAD (Eastman, C., et al., 2008:16). In CAD the building is represented as a two dimensional drawing as compared to a Building Model where it is represented as the building's actual construction and assemblies. Drawings in CAD are created by a collection of manually created files and coordinated lines allowing for inconsistencies to creep in whereas in BIM, the representations, plans, sections, elevations etc are generated from an interactive model (Krygiel, E and Nies, B, 2008:26-27). The other issue with CAD that has persisted for a long time now is the issue of data-exchange or interoperability and technical problems surfacing resulting from ways of saving and managing files in different software's (Tornincasa, S and Monaco, F,Di, 2010). Sharing of accurate and up to date information within team players is also a big difficulty in CAD.

BIM on the other hand promises a lot of benefits but in order for it to deliver one needs to go beyond the traditional line based approach to an object based technology. According to Wong et al and Rundell , BIM is gradually bringing about a change from 2 Dimensional or 3 Dimensional to much broader applications and opportunities (Wong et al, 2011:467) having implications for appropriate training and adequately skilled BIM proficient staff (Rundell, R., 2005). We have tabulated below benefits of BIM to various stake holders throughout the design, fabrication, pre and post construction stage which are illustrated in Table 2 below to show the various ways and extent to which BIM can be beneficial from the client/owner to other built professionals.

Table 2: Benefits of BIM during design, construction, operations and maintenance of a building project



[Source : Eastman, C; Building Smart; NBS; Smith, M.; Barlish,K.,& Sullina,K.,(2012) Azhar,S.,(2011)]

Table 3 below shows some real life projects where the use of BIM has brought about massive savings in time, project costs, production of drawings etc. among other benefits and has played a pivotal role from planning approval process to revealing clashes, gaining client confidence and post completion operations and maintenance. As is evident from the extent and varied nature of benefits reaped from employing BIM in the projects listed below, it is widely acknowledged and agreed that BIM brings umpteen benefits to the AEC industry and FM sector, but the real issue that still remains, and warrants careful consideration is whether we are ready to adopt it wholly, and if yes, more importantly what are the ways to overcome any barriers in its widespread and expeditious implementation in both practices and across Schools of Architecture in the UK.

Table 3: Examples of real life Projects employing BIM

Name of the Project	**Type of Benefit**
New Bridge Academy school, Hackney	Gained client confidence in explaining the complex design. (Building Smart , 2010:7)
Science Lab Plaza.	Liaise with city planners in the Planning approval process
The Bird's Nest Stadium	Allowed progress to be visualised by using the time dimension added to BIM with an IFC model linked to a 4D construction system
KLM's office, Endeavour house, Stansted	Project cost saving of 9.8% & 18% saved on cost of drawing production. (Building Smart, 2010a)
Hilton Aquarium,Atlanta, Georgia	590 conflicts identified between structural and MEP components with savings in time and $200,000. (Azhar, S., et al, 2008)
Palace Exchange, Enfield	Saved £50k plus improvements in spatial coordination and certainty of cost.
Festival Place, Basingstoke (Retail)	Saved 9% during the construction phase out of £110M. (Source : Building Smart, 2010a)
St Helens & Knosley Hospital facility	Completed six months prior to schedule Savings in time and design coordination by 60-70%
Sanger Institute, Cambridge	Operations and maintenance post completion of this new campus
Shanghai Tower	Improved sustainability analysis and cost savings in green elements. (McGraw-Hill cited in Bryde,D.,et al)
Sutter Health Medical Center	Benefit in criteria of 'Quality'. (McGraw-Hill cited in Bryde,D.,et al)

[Source: Building Smart, (2010, 2010a), Azhar,S., et al (2008) McGraw-Hill cited in Bryde,D.,et al]

In the next section we look at the myths, confusion, misunderstanding and uncertainties surrounding the implementation of BIM in both practices and schools so that ways can be identified to move forward and overcome the hurdles in successfully implementing BIM.

Uncertainties surrounding BIM – Status of implementation of BIM and impediments in its way

CPIC which is constituted by representatives from major UK industry institutions believes that proliferation of interpretations of BIM is coming in the way of its adoption to improve the construction industry. According to NBS's, National BIM Report 2012, the industry is currently not very clear about what BIM is and as a subject BIM is quite misunderstood. Watson also brings about this issue of uncertainty around BIM because of how it is perceived, is it modelling or a process, as is being more recently referred to or is it a Model or a product? (Watson, 2010).

Some of the generic issues surrounding BIM concern with ambiguity in relation to responsibility of the model's accuracy, challenges with teamwork and collaboration, legal changes with regards to documentation production and ownership of the multiple design, its fabrication and analysis. Another issue is the lack of a single treatise that instructs on the application of this new and sophisticated 3D collaborative BIM technology (AGC, 2005; Azhar,S; et al; 2008). Survey results from Yan and Damien in 2007 showed that there is lack of human resources and time and a myth that training existing staff would be quite expensive also causing impediments in its adoption.

Eastman supports the finding from Yan and Damien's survey and makes the point that not many design or construction teams are currently utilising BIM (Eastman, et al , 2008: 14). Another survey conducted in 2009 suggests that although 45% of the architectural practices are aware of BIM, but have not yet started employing it for a number of reason such as; disruption to their workflow (Suremann, 2009:30), requirement of staff skilled in use of BIM (Rundell, 2005), issues of investment in terms of expenditure incurred in training existing employees (Yan and Damien : 2008), expenditure incurred in purchasing the actual software(McGraw-Hill ,2010:13), legal and contractual issues (Thomsen and Miner, 2006), Interoperability (RAIC, 2010), inefficiency of using BIM on smaller projects and lack of client demand are among other reasons revealed by McGraw-Hill (McGraw-Hill, 2010:6). Table 4 below shows some of the issues and barriers in adoption of BIM.

Table 4: Issues and Barriers in the adoption of BIM in architectural practices

Issues / Obstacles / Impediments in implementation of BIM	**Authors/Scholars/ Organisations**
Confusion surrounding what BIM truly is and how to adopt and execute it an industry typically resistant to implement change.	NBS, (M.Smith, 2011)
Need for training & process change.	(BuildingSmart, 2010:1)
Everyone is not of the view that the time is right now.	
Practitioners being sceptical of adopting too soon a new approach.	(BuildingSmart, 2010:1)
Barrier to small firms – as BIM software's have to be bought in the first place.	(BuildingSmart, 2010:1)
Ambiguity in responsibility held by various stakeholders in the new process.	(Arayici,Y, et al, 2011)
Need a thorough understanding of networking and hardware for running BIM effectively.	(Arayici,Y, et al, 2011)
Interoperability issues with software.	(Becerik-Gerber,B.et al.,2010)
Lacking support in legal matters.	(Becerik-Gerber,B.et al.,2010)

Schools of Architecture and architectural practice are facing similar misconceptions about the reality of BIM and there seems to be a lack of understanding of its overall application. The issues in implementing BIM in

Schools of Architecture can be attributed to firstly lack of availability of people with the knowledge to teach it in and secondly the dilemma in deciding between teaching the technology or process behind BIM versus training students in a particular BIM software. According to Kymell, the three categories of barriers to BIM's introduction in the curriculum are misunderstanding of the BIM process, difficulty in learning and using BIM software by students and issues pertaining to the environment in the academic institution. Kymell considers misunderstanding of BIM concepts as the biggest hurdle in its adoption (Barison, M.B. and Santos, E.T., 2010b). Nancy Brown and Penne Robert have highlighted similar issues that have an impact on teaching BIM like emphasis on developing student knowledge as against computer skills and software knowledge, time required for student's learning modelling concepts, distinctive programme approach across various institutions for training and plenty of easy tools available for visualisation in the market (Brown, N. C. and Penna, R., 2009). A survey conducted by Sabongi and Becerik on 4 year undergraduate courses in the Schools of Construction in the US on the use of AutoCAD and BIM showed that the main impediments for the inclusion of BIM as part of the curricula was existing conditions for graduation, not enough space in curriculum for extra electives, dearth of BIM resource material and learning of BIM not yet identified as part of the accreditation criteria (Sabongi, J.F., 2009; Becerik et al., 2011). Figure 4 below shows the similar nature of barriers faced in both practice and education with implementing BIM that will need to be crossed if BIM is to be successfully implemented.

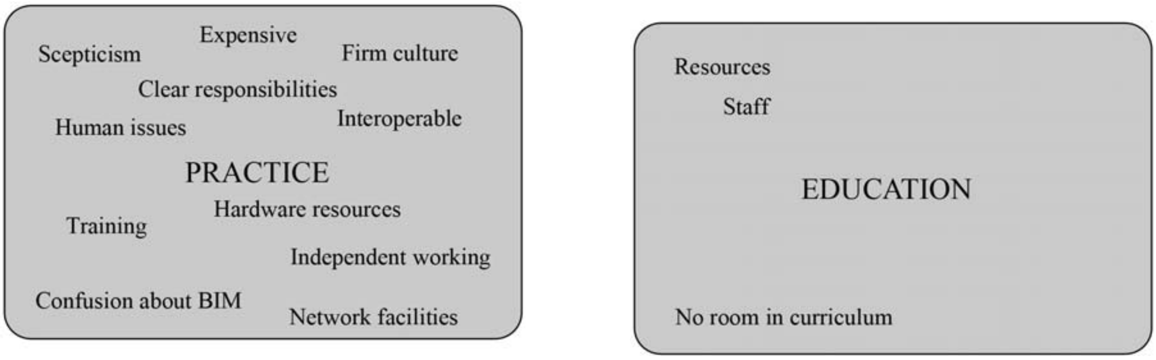


Figure 4. Barriers and obstacles in implementing BIM in Architectural Practices and Education
[Source : Authors own]

Many organisations, design and construction firms etc in response to meeting the growing demands of the profession are now looking to hire staff with BIM related job profiles like BIM specialist, Champion or an Administrator (J.E.Dunn, 2007 cited in E:134) and hence Sabongi (2009) believes that graduates with knowledge of BIM are nowadays more sought after by architectural practices. Cheng points to the fact that this type of expertise will however be hard – earned (Cheng, 2006). Very few Schools of Architecture have surprisingly taken the initiative to prepare their students for a BIM based environment and are still carrying on with teaching CAD used merely for drafting. Across the world many schools are either only teaching a few tools or have not even initiated the process of implementing BIM. As you will notice from table 5 below on status of implementation of BIM in Universities, many institutions predominantly in the US have started responding to this change, but unfortunately not much has been done by schools in the UK who seem to be fairly slow in its implementation. Since 2003 most schools in the US had begun introducing BIM with Georgia Institute of Technology and College of Architecture at Texas A&M University pioneering the field with teaching BIM much earlier on during the 90's. Table 5 below, shows the status of implementation of BIM within built environment related courses at Universities throughout the US and UK. The data has been collated to identify the level and course in which BIM is taught and the approach, emphasis or focus that has been adopted in teaching BIM.

Table 5: Status of implementation of BIM in Universities – Level and Approach adopted in teaching BIM

Name of Institution	**Year**	**Level/Course**	**Approach/Focus/Emphasis/Modules**	**Source**
University of Minnesota	2003	Graduate and Under Graduate		Autodesk, 2007
Madison Area Technical College	2003		BIM software in the course "Introduction to Architectural Third Party Applications"	MATC, 2003
Worcester Polytechnic Institute	2006	First & second year Civil Engineering		Salazar, et al., 2006
California State University	2004	Under Graduate	Specific BIM classes taught	Kymmell, 2008
Tongji University	2005	Civil Engineering & Construction Management	Interdisciplinary collaboration	Hu, 2007
Penn State University	2006		Integrated Design Studio using BIM	Onur, 2009
University of Wisconsin-Milwaukee			Computers in Architecture : BIM software	Stagg, 2009
California Polytechnic State University	2007		Building design course including students of Architecture, Engineering and Construction Management	Dong, 2009
Montana State University	2008	Under Gradaute	Teach BIM to Architecture students in Design and Graphics curriculum	Berwald, 2008
Auburn University			Week long tutorial followed by an introductory course that last for one semester.	Taylor, Liu &hein, 2008 cited in Sabongi, F.J.
New Jersey institute of Technology		Upper level studios	BIM class with main tools taught in the design studio environment.	Rudesill, 2007 cited in Sabongi, F.J.
BCA Academy of the Built Environment, Singapore		4 Day certificate course	To impart practical BIM modelling skills to start and support a BIM project	
University of Salford, Manchester		1 Year full Time MSc/PgDip/PgCert	BIM and integrated design	
University of Glamorgan Morgannwg	Sept 2013	1 Year full time Msc	BIM and Sustainability	
University of Wolverhampton	Oct 2013	PG Cert in Building Information Modelling	BIM Theory and Application BIM for Integrated Project Delivery Implementing and Managing BIM and CAD Systems	
Northumbria University	Sept 2013	1 Year full time Msc	Building Design Management and BIM	
International Academy of Design and Technology		Associates's of Science degree in BIM 20 months	To use CAD with design technology for completing working drawings	
University of Liverpool		One year Building Information Modelling MSc	To develop skills in the theory and practice of BIM in design and construction	
University of Virginia		Option Modules	BIM and revit1/BIM and Revit 2	
University of New South Wales, Australia		Year 2 Architecture – Module	Introduction to techniques of BIM- good model building practice- weekly lecture and 2 hr studio	

The inferences that can be drawn from the above tabulated information, is that currently the programmes initiated in the UK have been at the Masters level i.e 1 year MSc’s and BIM has not been introduced and integrated as part of the UG curriculum in comparison to some of the Universities in the US, Australia and Singapore as mentioned in table 5 above. It can also be inferred that the focus of BIM courses introduced I the UK is on BIM and integrated design, sustainability, managing BIM, building design management and BIM theory and application. In comparison, other Universities outside the UK focus more on the actual modelling skills, techniques and software’s integrated in the design studio and usually taught through specific BIM classes, tutorial, seminar.

A study by Barison and Santos, categorised the various courses where BIM has been introduced so far: Digital Graphic Representation (DGR), Workshop; Design studio; BIM course; Building Technology; Construction Management; thesis project and Internship (Barison, M.B. and Santos, E.T., : 2010b). It also showed that BIM is introduced in most schools in only one discipline (i.e. Architecture or Engineering) with students of the same course and less than 10% of schools attempt to simulate the inter-disciplinary collaboration at the same school. It was also found that BIM was introduced in the design studio as the predominant approach of many architecture programmes. The survey showed that 50% of the schools were introducing BIM as a design studio course, approx 13% taught BIM in courses related to Deign graphic representation and 10% as an elective module and the other options (less than 5%) were to teach BIM in construction management or offer BIM as workshop.

Implementation of BIM in the architectural curricula and way forward

The Royal Institute of British Architects (RIBA) has recently highlighted that in order to adopt BIM technology, it is critical to re-educate/re-skill the professionals within the industry and we can start that by integrating BIM early on in the curriculum (RIBA 2011). Hence, ppressure is mounting on architectural schools in the UK from all sides including the professional body, architectural practices and the government to urgently integrate BIM into the curriculum and prepare graduates entering the work arena to be equipped to be competent and proficient in the use of BIM. Deutsch in “BIM Beyond Boundaries” is of the view that specialization in BIM would counter-intuitively demand unlearning and detachment and require new collaboration skills coupled with broad interests that will have to be imparted in the training of students. There is thus a growing need for students, existing professionals and practices to not only be aware of the increasingly important role BIM plays in the AEC and FM industry, but more importantly be adequately trained and retrained in adopting BIM into there work environment. It is therefore important to analyse the initiatives taken around the world to introduce BIM in order to share best practice and ascertain how best BIM can be fully integrated into the students learning before they enter the work arena.

According to the AIA’s report on Integrated Practice on BIM:

> “Regardless of the magnitude of BIM’s eventual of impact on the profession, its recent rise provides the ideal catalyst for rethinking architectural education. The level of experience required to intelligently design what BIM is significant, and serious consideration must be given to how it can be taught”(Cheng, 2006).

There are many different approaches in introducing BIM in the architecture curricula but there is no clear consensus on how it should ideally be taught as there are many divergent practices or approaches currently in place and it is still early days to gauge the effectiveness of the pedagogy employed. The steps that should be taken to implement BIM in the architecture curricula in the school of architecture are not very different from implementing it in an architectural practice which includes first creating a BIM adoption or implementation plan that covers all aspects of its content and delivery and measures its impact both internally and externally.

Survey Questionnaire findings, model for teaching BIM and Conclusion -

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